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00616 | Research Article

Environmental and Economic Impacts of Rapid Population Growth on Natural Resources in Eleme

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Abstract

This study assesses the environmental and economic consequences of rapid population growth and unsustainable natural resource use in Eleme Local Government Area of Rivers State, Nigeria. Using geospatial analysis of land-use/land-cover (LULC) changes from 2006 to 2024 combined with statistical correlation techniques, the research evaluates how demographic pressures have transformed the local landscape. Results show that accelerated population growth has driven extensive conversion of dense vegetation into light vegetation and agricultural land, alongside the reduction of water bodies and the expansion of built-up areas. These trends are attributed to increasing demand for housing, farmland, fuelwood, and other livelihood resources. Statistical analysis indicates strong negative correlations between population growth and the extent of water bodies, light vegetation, and dense vegetation, demonstrating the direct ecological impacts of uncontrolled demographic expansion. Economically, the degradation of natural resources has contributed to declining agricultural productivity, rising costs of resource extraction, loss of ecosystem services, and increasing pressure on public infrastructure. The study highlights the urgent need for integrated population management and sustainable resource governance. It recommends targeted interventions, including improved spatial planning, community-based resource management, reforestation and wetland restoration initiatives, and increased public investment in education, health, and job creation to promote sustainable livelihoods and long-term environmental resilience in the region.

Keywords

Environment; Ecosystems; Water bodies; Vegetation; Rivers state

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Introduction

Strain on natural resources has intensified in the 21st century, posing significant risks to public health and development. Issues such as water scarcity, soil depletion, deforestation, pollution of air and water, and coastal degradation have become prevalent in numerous regions. With the global population on the rise, the challenge of enhancing living standards without compromising the environment has emerged as a critical concern worldwide (Hinrichsen and Bryant, 2010). Current estimates suggest that the demand for forest products may exceed sustainable consumption levels by approximately 25 percent (Gardner-Outlaw and Engelman, 1999; Wackernagel *et al*, 1997). The bulk of this demand originates from developed countries. Despite representing only 16 percent of the global population, North America, Europe, and Japan account for two-thirds of the world's consumption of paper and paperboard, as well as half of its industrial wood (Abramovitz, 1998; Wilkinson, 1992). Additionally, while the demand for industrial wood products is increasing in developing nations, there is also a growing need for fuelwood, which serves as the primary energy source for many rural populations (FAO, 1999).

During the 1990s, many rapidly growing developing nations experienced high deforestation rates (Kopnina and Washington, 2016). Forested land was often cleared for agricultural purposes, and trees were harvested for housing and fuel. Furthermore, these countries increased their exports of forest products to satisfy the rising demand from developed nations. Research by Gardner-Outlaw and Engelman indicates that the per capita forest area halved between 1960 and 1995, a trend driven by both population growth and the loss of forest cover. By 1995, approximately 1.7 billion individuals resided in countries where forest cover was less than one-tenth of a hectare per person. They project that by 2025, this number could rise to an estimated 4.6 billion people living in similar conditions (Gardner-Outlaw and Engelman, 1999).

According to the FAO (2018) projections, the global urban population will increase by 70% by 2050, leading to the expansion of metropolitan areas and an increase in natural resource consumption, which will negatively impact human health (Semeraro *et al*., 2021). The expansion of urban areas over time has led to the depletion of natural resources and environmental degradation, particularly green spaces, as shown by studies investigating land use and land cover changes (Azhar *et al.*, 2024; Puplampu and Boafo, 2021).

Urban expansion poses significant threats to green spaces, jeopardizing their ecological integrity and the numerous benefits they provide to urban communities. Recent studies highlight the escalating pressures on green spaces due to infrastructure development, population growth, and land-use changes (Bhalli *et al*., 2013; Bhalli and Ghaffar, 2015; Minallah *et al*., 2016a; Minallah *et al*., 2016b) associated with urbanization (Bhalli, Ghaffar and Shirazi, 2012a; Soga, Yamano and Koike, 2022). These threats include habitat loss, fragmentation, and degradation, leading to declines in biodiversity and ecosystem services (Petrukha *et al*., 2025; Zhang *et al*., 2021). The Economic Commission for Africa (ECA, 2001) observed that, in "The State of Demographic Transition in Africa", published in 2001, the demographic transition in selected countries of Africa has been a consequence of two major factors: an increase in the age at marriage and control of marital fertility. Socio-economic changes, especially with regard to better

educational and health care systems, and a well-planned, carefully executed family planning system, contribute to the transition. Additional factors include societal changes, extension of social benefits to a wide spectrum of the population, investment in key physical and institutional infrastructure for service delivery, and efforts made to close the gender gap in accessing education and employment, particularly for women.

For countries such as Botswana, Mauritius, and Tunisia, the challenge is sustaining the transition without falling below replacement fertility. For countries that are in early stages of the transition, the challenge is for them to adapt and practice the lessons learnt from Botswana, Mauritius, and Tunisia while avoiding the mistakes made by Cameroon, Mali, and Nigeria. The demographic dividend refers to the accelerated economic growth that begins with changes in the age structure of a country's population as it transitions from high to low birth and death rates. With fewer young people relative to the population of working-age adults, and with the successful implementation of key national policies over the long term, countries such as Thailand and Brazil have reaped many rewards from their demographic dividend (James and Jason, 2012).

As a country's total fertility rate (TFR, the average number of children per woman) drops, the proportion of the population under age 15 begins to decrease relative to the adult working-age population (generally ages 15 to 64, the child dependency ratio). The decline in this ratio sets the stage for smaller families, who now have more resources to invest in the health, education, and well-being of each child. And with fewer people to support, a country has a window of opportunity for rapid economic growth if the right social and economic policies are developed and investments made. As long as the child dependency ratio continues to decrease, the window remains open. Eventually, however, people ages 65 and older begin to represent an increasingly larger proportion of the total population, signaling the end of the first demographic dividend.

From a demographic perspective, these changes in the population age structure characterize the time frame during which a dividend can take place. But changes in the population age structure do not guarantee accelerated economic growth; the dividend is not automatic and requires a set of investments and policy commitments (James and Jason, 2012). Eleme has significant economic potential but faces severe environmental challenges, including pollution of groundwater and land, as highlighted in the United Nations Environment Programme's report on the Environmental Assessment of Ogoniland (UNEP, 2011). The region is also experiencing rapid population growth driven by immigration and economic opportunities. This study examines the impacts of population growth on natural resource use and environmental quality in Eleme. Using Geographic Information Systems (GIS), Remote Sensing (RS), demographic analysis, and statistical techniques, the research assesses how population dynamics shape patterns of resource exploitation and identifies sustainable pathways for managing Eleme's natural resources.

Methodology

Study Area

Eleme is a Local Government Area located in Rivers State, Nigeria, positioned between longitudes 7° and 7°15′ East and latitudes 5°00′ and 4°35′ North (Figure 1). Covering

approximately 120 km², the area recorded a population of 190,194 in the 2006 census, with substantial growth projected in subsequent years. Eleme gained national and international prominence following the discovery of significant oil and gas reserves in 1956, which attracted more than one hundred companies involved in upstream and downstream petroleum operations. The Onne Port Complex, situated within the area, has evolved into one of the most active maritime and petroleum logistics hubs in sub-Saharan Africa (Obenade *et al*., 2020).

Eleme Local Government Area is situated at the western fringe of Ogoniland and is divided into ten clans organized into two political blocs: the Nchia bloc, which consists of six clans (Akpajo, Aleto, Alesa, Alode, Ogale, and Agbonchia), and the Odido bloc, which includes four clans (Onne, Ebubu, Eteo, and Ekporo). Each clan contains various sub-communities; for example, the Ebubu clan comprises Ejamah, Ochani, Obollo, Egbalor, and Agbeta. The oilfields in Eleme LGA, located in areas such as Ebubu (Ejamah, Agbeta, Obollo, Egbalor), Ogale (Ajioepuori, Nsisioken, Obajeaken), and Onne (Ekara), were discovered in October 1956. Notably, the first shipment of crude oil exported from Nigeria to Europe in 1958 included oil extracted from Eleme, amounting to 22,000 barrels. The communities within Eleme are home to several significant national and international institutions, with the Imu Ngololo River serving as the main waterway, which hosts the Nigerian Naval College along its banks (Obenade *et. al*., 2020).

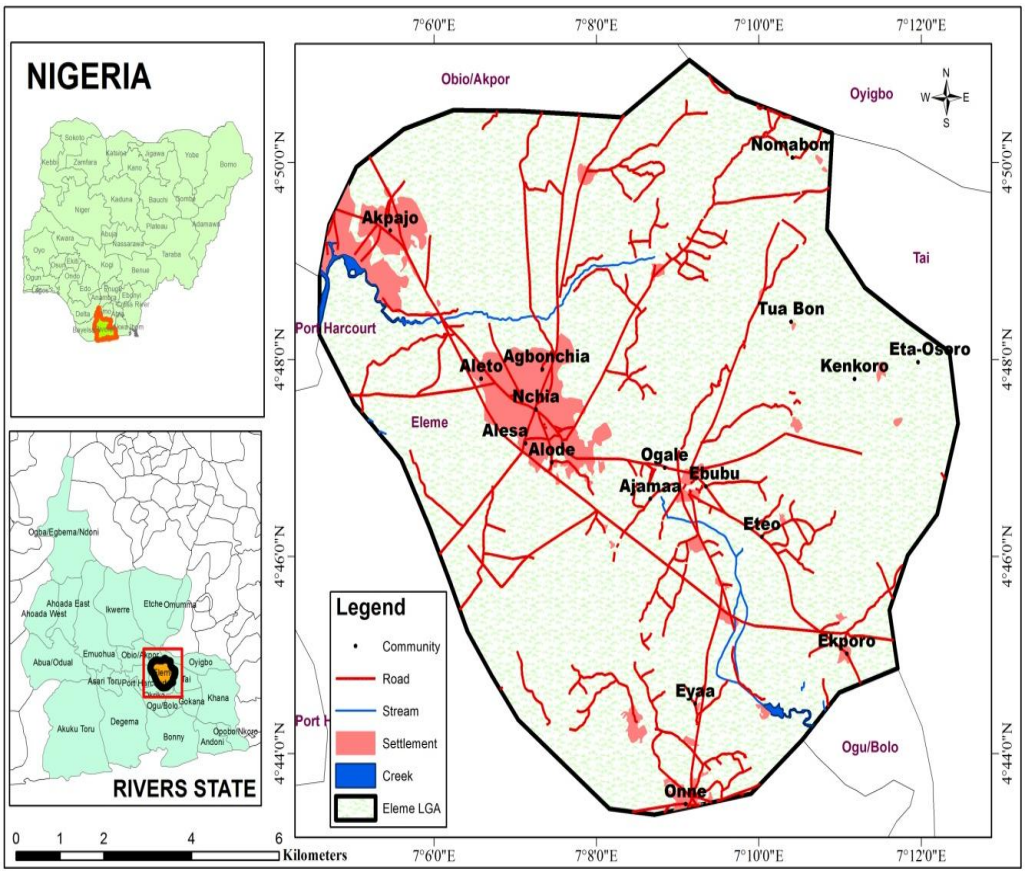

Figure 1: Map of the Study Area (Eleme)

The aquifers in Eleme are essential for the drinking water supply of the local population, making their protection crucial. These aquifers are relatively shallow, with groundwater levels found from just below the surface to depths of about 10 meters. To access these aquifers, residents commonly dig open wells with a diameter of approximately 60 cm, from which water is extracted manually or with pumps. In areas where surface water pollution is an issue, wells may reach depths of up to 50 meters, requiring immersible pumps for water retrieval. Seasonal fluctuations significantly influence water levels in these aquifers (UNEP, 2011). The coastal area of Eleme is divided into three unique vegetation zones: (i) the beach ridge zone, (ii) the saltwater zone, and (iii) the freshwater zone. The beach ridge zone is noted for its mangroves found in tidal flats, along with swamp trees, palms, and shrubs that thrive on sandy ridges. The saltwater zone is primarily dominated by red mangrove (Rhizophora mangle), whereas the coastal plain and freshwater zone support various forest tree species and oil palm (UNEP, 2011).

Data Type

The study utilized topographic maps, multi-date satellite imagery, and administrative maps (Table 1).

Table 1: Characteristics of Data Used

S.N.	*Type*	*Format*	*Path/Row*	*Scale/Solution*	*Date Source*
1.	Topographic	Analogue	Port-Harcourt/329	1:50,000	1974/OSGOF
2.	Landsat TM	Digital	P188R57	30m	1986/Glovis
3.	Landsat ETM	Digital	P188R57	30m	2006/Glovis
4.	Landsat 8	Digital	P188R57	30m	2015/Glovis

Development of a Classification Scheme

The classification scheme was developed using the researcher's knowledge of the study area, reconnaissance surveys, previous studies, and FAO Land Cover Classification System guidelines. They include Built-up area (BA), Farm/fallow land (FL), Water body (WB), Thick Vegetation (VG), and Light Vegetation (LVG) as shown in table 2.

Table 2: Classification Scheme

Code	*Land Cover Categories*
FA	Farmland
LV	Light Vegetation
BL	Built-up land
TV	Thick Vegetation
WB	Water bodies

Supervised Classification

Supervised classification is an essential tool for extracting quantitative information from remotely sensed imagery (Richards, 1993). This technique was adopted to extract quantitative information from the satellite images. It requires selecting representative

training sites from known land cover types. Once training samples are defined, the classifier labels all image pixels according to their spectral signatures. The Maximum Likelihood Classification (MLC) algorithm was used due to its robustness and its assumption that each land cover class follows a multivariate normal distribution. Five training sites were assigned and categorized into the predefined land cover classes.

Table 2.1: Error Matrix and Kappa Analysis

Year	*Kappa Coefficient*	*Overall Accuracy*
1986	1.0	100%
2006	1.0	100%
2015	0.83	90%
Average	0.94	96.6

Change Detection

Change detection techniques were applied to evaluate land cover dynamics over the study period (1986–2015). These methods support environmental managers and planners in understanding patterns of land use transformation. Multiple approaches were employed, acknowledging that different methods produce varying outputs (Araya and Cabral, 2008).

Image Differencing

This method involves subtracting pixel values of an image from one date from the corresponding pixels of another date (Singh, 1989; Tardie and Congalton, 2004).

(Difference Image) = DN_{t2} - DN_{t1}
Unprocessed (raw) images often produce inconsistent results; therefore, preprocessing steps were conducted before differencing.

Vegetation Index Differencing

The Normalized Difference Vegetation Index (NDVI) was computed to quantify changes in vegetation cover. NDVI is one of the most common vegetation indexing methods and is calculated by:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad 1$$

Where NIR is the near infrared band response for a given pixel, and RED is the red response

Map Data Processing

The maps procured for this study include: topographic and administrative maps covering the study area. These maps were used as ancillary data to aid field work, image classification, and the compilation of maps produced in the research work. The Topographic and administrative maps covering Eleme were scanned, geo-referenced,

and subset to the area of interest. They were digitized to extract thematic layers, which were integrated into the geographic database to support field validation, image classification, and map production.

Remote Sensing Data

Present and past information on land cover and land use change for the study area was generated from multi-date remotely sensed data, which was used to evaluate sprawl. Land cover and land use information were extracted from multi-date satellite imagery (1986, 2006, and 2015). These datasets supported the evaluation of urban expansion and ecological changes. SPOT-5 imagery, with a spatial resolution of 5 m, was additionally used to enhance image interpretation and classification accuracy.

Population Estimates

Population estimates for the years 2007 and 2015 were calculated using the 2006 population data for Eleme, applying the National Population Commission's (NPC) recommended growth rate of 3.4 percent derived from the 2006 census. To estimate the population figures, the growth rate was first multiplied by the 2006 census number for Eleme, and the result was then divided by 100. This figure was subsequently multiplied by the number of years projected and added to the population from the base year (2006). The formula used for these calculations is as follows:

$$n = \frac{r}{100} * PO \quad (2)$$

$$Pn = \sum(PO + (n * t)) \quad (3)$$

Where:
P_n = projected population (for 2007, 2019)
P_O = population in the base year (2006)
r = growth rate (3.4%)
n = annual population increase
t = number of years for projection

In assessing the socio-economic impacts of changes, the variations in land use and land cover observed between 1986 and 2015 were utilized as key criteria.

Statistical Analysis

The Multiple Correlation Technique was employed to analyze the relationship between population growth and various land use variables (including built-up areas, farmland, light vegetation, thick vegetation, and water bodies) to assess the impact of population growth on land cover changes. In this analysis, population growth serves as the independent variable (X), while land cover elements act as the dependent variables (Y). This relationship is represented as follows:

$$r = r^2yx_1 + \ldots\ldots r^2yx_n\text{-}2rx_1y_1ryx_n, rx_1x_2$$

Where:

r = correlation coefficient
y = land cover types
x_1- x_n = population at different years

Results and Discussion

Table 3 presents the age and sex distribution of Eleme based on the 2006 National Population and Housing Census. The results indicate that 80.2% of the population falls within the age bracket of 0–39 years, confirming that Eleme has a predominantly young and youthful population. This supports the position of Makama (2010) and is visually reinforced by the population pyramid shown in figure 2.

Table 3: Distribution of Population (2006) by Five-Year Age Groups and Sex

Age Groups	*Sex*		
	Total	*Males*	*Female*
ELEME			
Total	190,194	98,345	91,849
0 - 4	21,651	11,217	10,434
5 - 9	24,307	12,628	11,679
10 - 14	23,476	12,432	11,044
15 - 19	23,013	12,004	11,009
20 - 24	19,803	10,098	9,705
25 - 29	16,731	7,742	8,989
30 - 34	12,564	5,651	6,913
35 - 39	10,977	4,932	6,045
40 - 44	9,965	5,167	4,798
45 - 49	8,149	4,453	3,696
50 - 54	6,853	3,981	2,872
55 - 59	3,281	1,956	1,325
60 - 64	3,987	2,592	1,395
65 - 69	1,640	962	678
70 - 74	1,507	1,076	431
75 - 79	600	355	245
80 - 84	840	549	291
85+	850	550	300

Source: NPC Priority Table Volume IV, 2010 (2006 Population and Housing Census)

The pyramid shows a broad base typical of populations with high fertility and relatively young age structures. The large proportion of children (0–19 years) accounting for 48.6% of the total population signifies high birth rates, while the narrow apex suggests that relatively few individuals survive into old age. As a result, the demographic structure of Eleme carries an inherent population growth momentum, which partly explains the rapid population increase observed over the past 75 years.

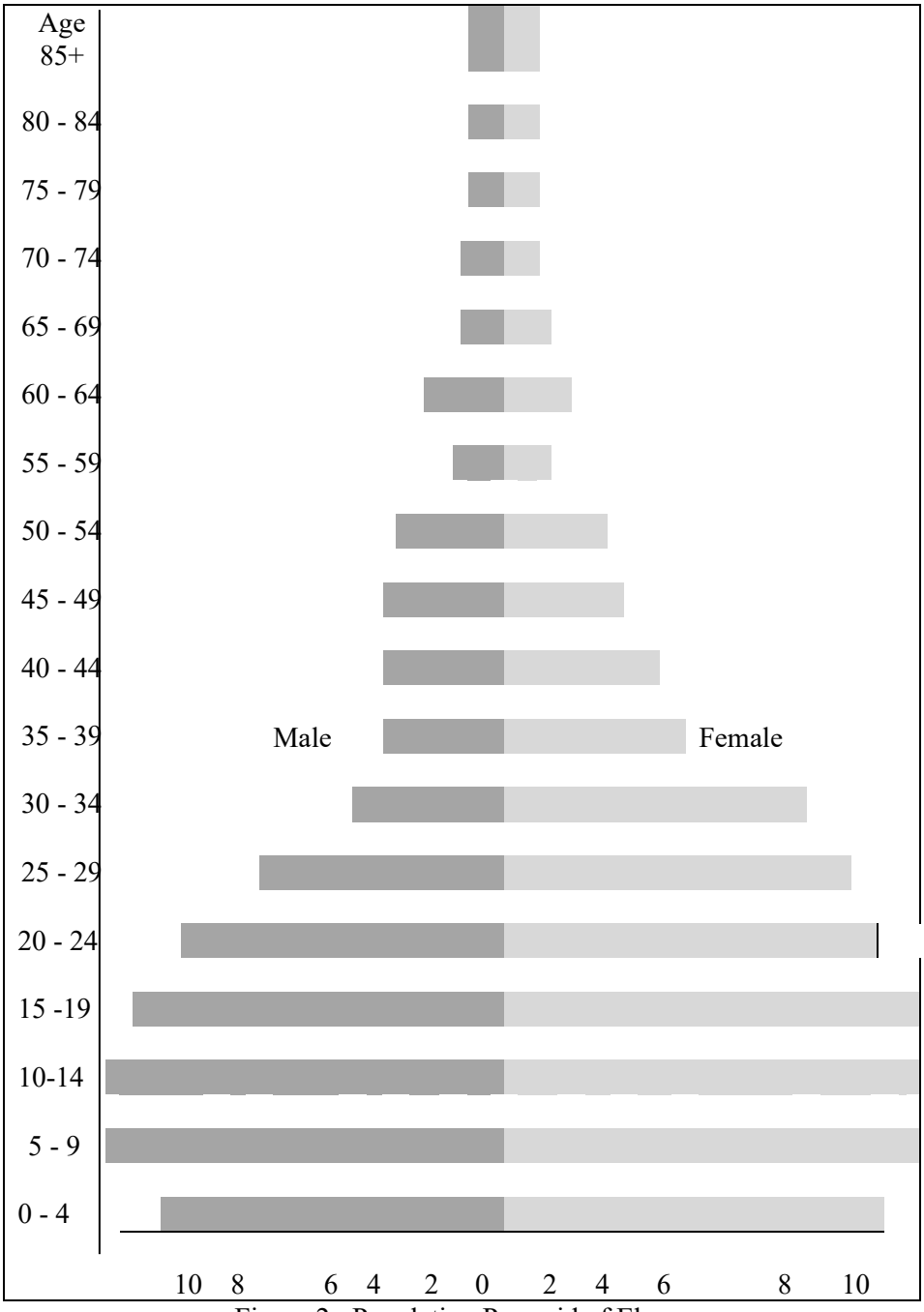

Figure 2: Population Pyramid of Eleme

Population Growth Trend in Eleme (2006–2024)

Table 4 shows the population projections for Eleme using the 2006 census figure (190,194) as the base year and an annual growth rate of 3.4%, the national average. The projections reveal that the population grew to 347,526 in 2024, representing a 54.73% increase over the 18 years. At this growth rate, population doubling is expected within

25–30 years, consistent with demographic projections. This significant increase is also influenced by net migration, particularly due to oil and gas activities that attract workers and ancillary industrial developments. Figure 3 illustrates the clear upward trajectory of population growth between 2006 and 2024.

Table 4: Population Growth in Eleme

Year	*Population*	*Projected Population Increase in Eleme Using 3.4 % Growth Rate*
2006	190194	6467
2007	196661	6686
2008	203347	6914
2009	210261	7145
2010	217410	7392
2011	224802	7643
2012	232445	7903
2013	240348	8172
2014	248520	8450
2015	256970	8737
2016	265707	9034
2017	274741	9341
2018	284082	9659
2019	293741	10281
2020	304022	10337
2021	314359	10688
2022	325047	11052
2023	336099	11427
2024	347526	11816

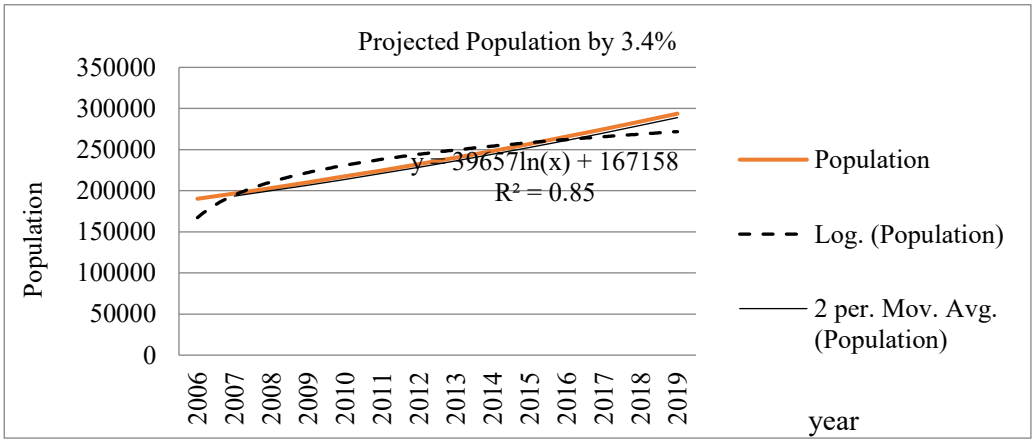

Figure 3: 3.4 % Growth Rate Projected Population Increase in Eleme prepared by the Authors

Figure 3 gives a graphical indication that population growth in Eleme is on the increase and that this trend will continue over time. This trend of growth shows the growth rate trajectory from 2006 to 2019, with the estimated annual growth rate of 3.4%. It is imperative to state that the population growth rate of 3.4% does not account for the annual births, deaths, and immigration into the area by job seekers, and therefore becomes a limitation in estimating the exact growth rate in Eleme.

Population Growth and Land Use Change Dynamics (2006–2024)

Table 5 provides a combined assessment of population growth and land use transitions in Eleme over the 19 years. As the population increased, there was a consistent expansion in built-up areas, rising from 18.67% in 2006 to 60.16% in 2024. Correspondingly, farmland, light vegetation, thick vegetation, and water bodies all declined.

Table 5: Population Growth and Land Use Change Trend in Eleme (2006 – 2024)

Year	*Population Growth*	*Built-up Area*	*Farmland*	*Light Vegetation*	*Thick Vegetation*	*Water Body*
2006	6273	18.67	24.3	76.79	16.09	2.25
2007	6467	20.805	24.653	75.213	15.146	2.105
2008	6686	23.12	25.006	73.636	14.202	1.96
2009	6914	25.435	25.359	72.059	13.258	1.815
2010	7149	27.75	25.712	70.482	12.314	1.67
2011	7392	30.065	26.065	68.905	11.37	1.525
2012	7643	32.38	26.418	67.328	10.426	1.38
2013	7903	34.695	26.771	65.751	9.482	1.235
2014	8172	37.01	27.124	64.174	8.538	1.09
2015	8450	39.325	27.48	62.59	7.594	0.945
2016	8737	41.64	27.83	61.013	6.65	0.8
2017	9034	43.955	28.183	59.436	5.706	0.655
2018	9341	46.27	28.536	57.859	4.762	0.51
2019	9659	48.585	28.889	56.282	3.818	0.365
2020	10281	50.9	29.242	54.705	2.874	0.22
2021	10337	53.215	29.595	53.128	1.93	0.075
2022	10688	55.53	29.948	51.551	0.986	0.07
2023	11052	57.845	30.301	49.974	0.042	-0.075
2024	11427	60.16	30.654	48.397	-0.902	-0.22

Land Use Change Patterns

Figures 4 and 5 depict the spatial and temporal dynamics of land use change: Built-up areas expanded sharply, particularly between 2006 and 2015. Farmland decreased moderately, suggesting conversion of agricultural space to residential and industrial uses. Light and thick vegetation declined exponentially, reflecting rapid deforestation, habitat fragmentation, and ecosystem degradation. The water body has been reduced continuously, indicating shrinkage and possible drying up linked to pollution, sand mining, and land reclamation.

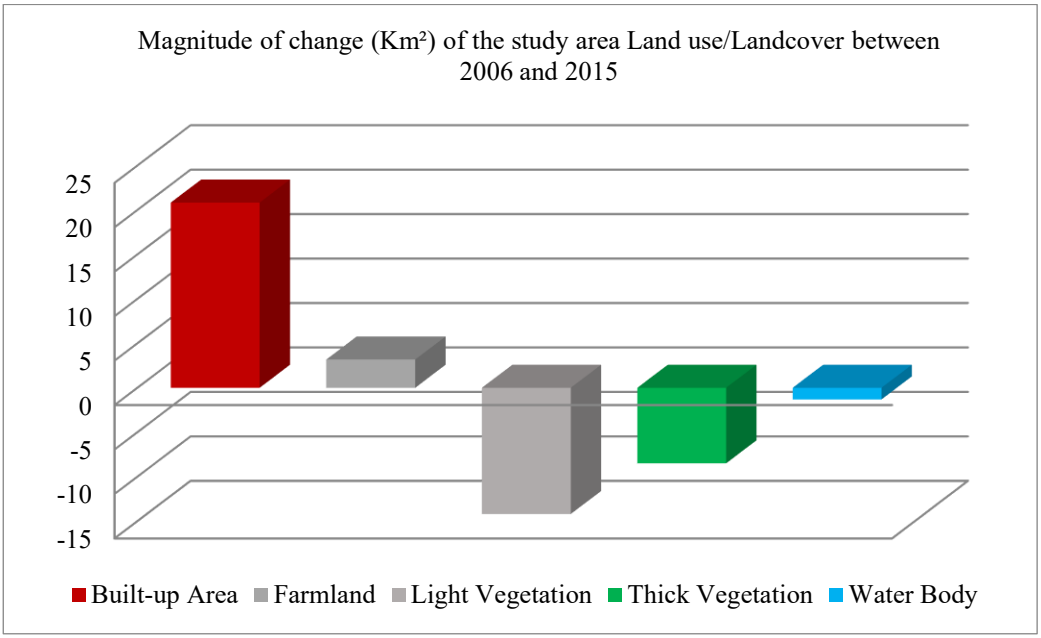

Figure 4: Land Use Change of Eleme between 2006 and 2015, prepared by the Authors

Figure 4 shows the inverse and reciprocal relationships among the variables. An increase in built-up area results in a reduction in farmland and an exponential decrease in light and thick vegetation in an unsustainable manner, and it has dire consequences on the ecosystems.

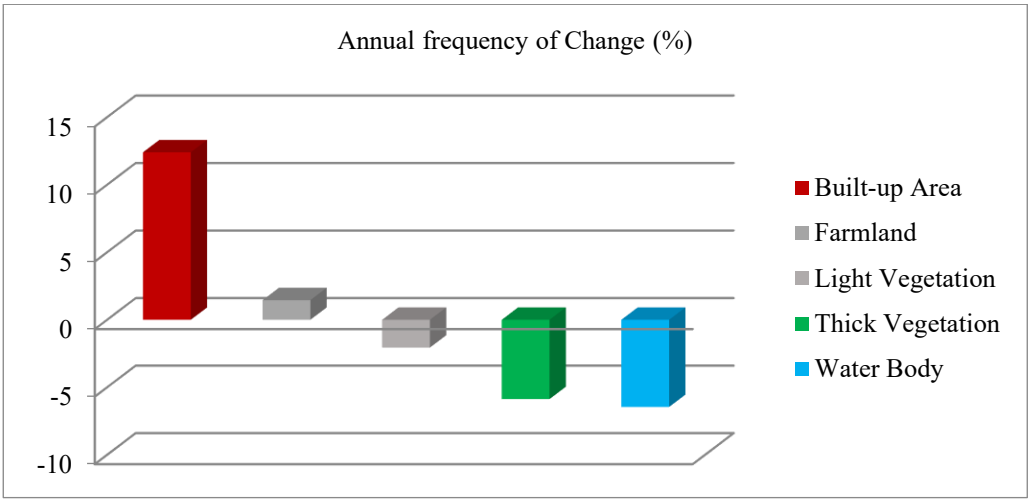

Figure 5: Annual Frequency of Land Use Change (%) in Eleme between 2006 and 2015

Figure 5 above shows the annual frequency of land use change that occurred in Eleme between 2006 and 2015, which is negative for thick vegetation and water bodies. This will invariably lead to shrinking or drying up of water bodies in the area and the dangers it portends to the environment. Figure 6 further confirms that land development between

2006 and 2015 was more extensive than between 1986 and 2006, correlating with higher population growth and intensified industrialization during this period. Overall, these changes signal unsustainable pressure on Eleme's ecosystems, with implications for biodiversity loss, declining agricultural productivity, and increased vulnerability to environmental hazards.

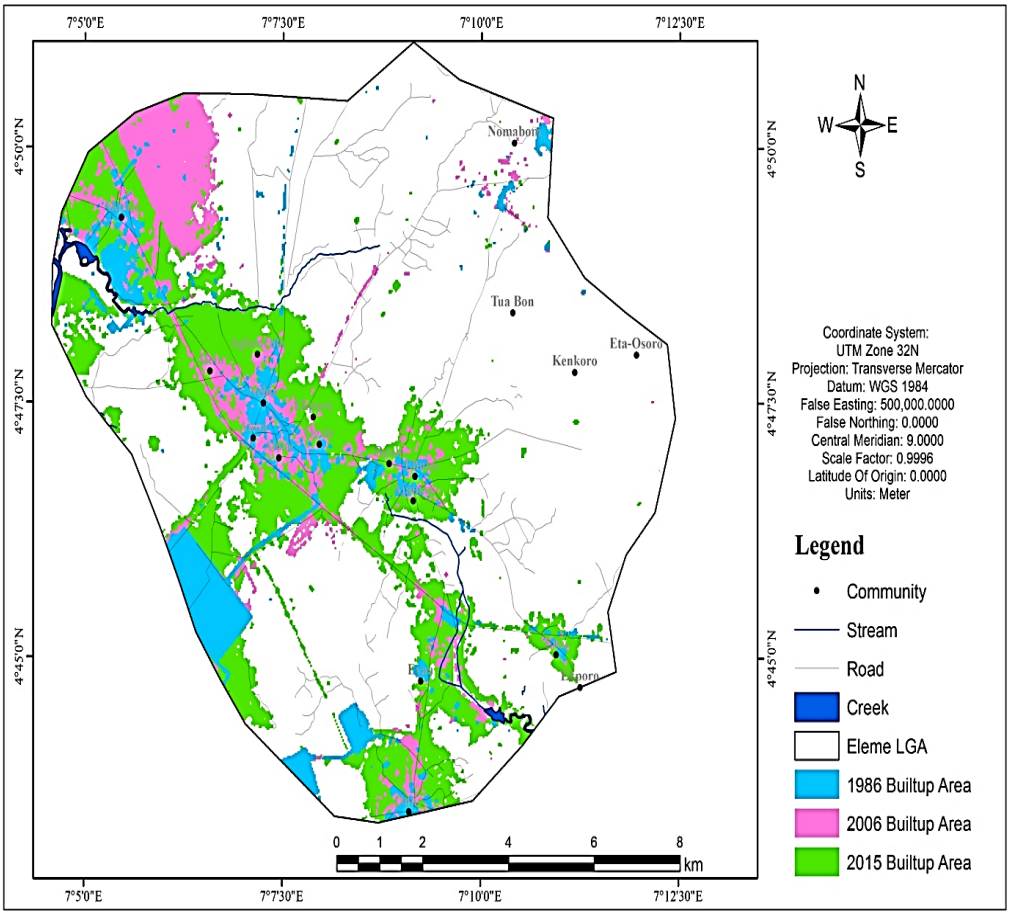

Figure 6: Image of Built-up Area Distribution in Eleme between 1986 and 2015

Figure 6 above is the superimposition of the satellite images of 1986, 2006, and 2015 to form one image, which represents the extent of (built-up areas) development/activities that took place during each period. It could be seen that more development took place between 2006 to 2015 than between 1986 to 2006. This could partly be explained by the increase in population that created demand for houses, industries, infrastructure like schools, health facilities, and indeed supply, among others.

Analysis of Variance (ANOVA)

Table 6 presents the ANOVA results for the six variables under study. The high F-statistic (527.8977) shows that significant differences exist among the mean values of the variables, confirming that population growth and land use changes are interrelated.

The F-statistic of 527.8977, which exceeds the critical F-value of 2.298431, indicates a statistically significant relationship among the land-use variables.

Table 6: Analysis of Variance (ANOVA) technique

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Population Growth	19	163605	8610.789	2651389		
Built-up Area	19	747.355	39.33447	169.2938		
Farmland	19	522.066	27.47716	3.945952		
Light Vegetation	19	1189.273	62.59332	78.80796		
Thick Vegetation	19	144.286	7.594	28.21931		
Water Body	19	18.375	0.967105	0.614409		
ANOVA						
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.17E+09	5	2.33E+08	527.8977	3.69E-74	2.298431
Within Groups	47730055	108	441945			
Total	1.21E+09	113				

In table 6, the results indicate that built-up area is positively associated with population growth, although the relationship is statistically insignificant. A 1% increase in built-up area is associated with an increase of 1,253.760 in population growth; however, this relationship is insignificant because $|t| < 1.96$, indicating non-significance at the 5% level. For farmland, a 1% increase leads to a reduction in population growth by 49,241.21, but this relationship is also statistically insignificant, as indicated by the absolute t-statistic of 1.007009, which is less than 1.96.

Similarly, light vegetation shows a negative and insignificant relationship with population growth. A 1% increase in light vegetation reduces population growth by 9,078.109, with an absolute t-statistic of 0.438642 - well below 1.96. For thick vegetation, a 1% increase corresponds to a decrease of 737.3682 in population growth, and this effect remains statistically insignificant given its very low absolute t-statistic (0.024371). In contrast, water bodies exhibit a positive and statistically significant relationship with population growth. A 1% increase in water body area increases population growth by 1,767.189, and the absolute t-statistic of 2.164633 exceeds the 1.96 threshold, indicating statistical significance.

Multiple Regression Analysis

Table 7 reveals the influence of each land-use variable on population growth, using Multiple Regression Analysis. Table 7 reveals the influence of each land-use variable on population growth:

Table 7: Multiple Regression Technique

Dependent Variable: POPULATION_GROWTH				
Method: Least Squares				
Date: 10/02/25 Time: 01:17				
Sample: 2006 2024				
Included observations: 19				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
BUILT_UP_AREA	1253.760	840.8704	1.491026	0.1598
FARMLAND	-49241.21	48894.53	-1.007090	0.3323
LIGHT_VEGETATION	-9078.109	20695.94	-0.438642	0.6681
THICK_VEGETATION	-737.3682	30255.51	-0.024371	0.9809
WATER_BODY	1767.189	816.3921	2.164633	0.0496
C	1884423.	2176613.	0.865759	0.4023
R-squared	0.995709	Mean dependent var		8610.789
Adjusted R-squared	0.994059	S.D. dependent var		1628.309
S.E. of regression	125.5103	Akaike info criterion		12.75474
Sum squared resid	204786.8	Schwarz criterion		13.05299
Log likelihood	-115.1700	Hannan-Quinn criterion		12.80522
F-statistic	603.3228	Durbin-Watson stat		1.340442
Prob(F-statistic)	0.000000			

Correlation coefficients in table 7 indicate very strong linear associations among variables, with built-up area and farmland positively correlated with population growth, and vegetation and water bodies negatively correlated. However, the regression coefficients show that only water bodies exhibit a statistically significant relationship with population growth ($p < 0.05$), while the other predictors are not significant at the 5% level. Multiple Comparison Tests (Bonferroni Adjustment):

- It implies that there is a strong negative correlation between light vegetation and population growth.
- Thick vegetation: Given that the value of 0.995955 is close to one (1) with a negative sign, it shows that there is a strong negative correlation between thick vegetation and population growth.
- Water body: Given that the value of 0.992069 is close to one (1) with a negative sign, it shows that there is a strong negative correlation between water body and population growth.

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Table 8: Multiple Correlation Analysis

	Population_ Growth	Built_Up_ Area	Farmland	Light_ Vegetation	Thick_ Vegetation	Water_ Body
Population_Growth	1.000000	0.996072	0.995947	-0.995954	-0.995955	-0.992069
Built_Up_ Area	0.996072	1.000000	0.999996	-0.999996	-0.999996	-0.998621
Farmland	0.995947	0.999996	1.000000	-1.000000	-1.000000	-0.998658
Light_ Vegetation	-0.995954	-0.999996	-1.000000	1.000000	1.000000	0.998660
Thick_ Vegetation	-0.995955	-0.999996	-1.000000	1.000000	1.000000	0.998656
Water_Body	-0.992069	-0.998621	-0.998658	0.998660	0.998656	1.000000

In table 8 above, Built-up area: Given that the Bonferroni adjusted probability value of 0.0034 is less than 0.05, this implies that the relationship between population growth and built-up area is statistically significant after Bonferroni adjustment. Farmland: Given that the Bonferroni-adjusted probability value of 0.0098 is less than 0.05, this implies that the test is significant between the population growth and farmland.

- Light vegetation: Given that the Bonferroni-adjusted probability value of 0.0053 is less than 0.05, this implies that the test is significant between the population growth and light vegetation.
- Thick vegetation: Given that the Bonferroni-adjusted probability value of 0.0012 is less than 0.05, this implies that the test is significant between the population growth and thick vegetation.
- Water body: Given that the Bonferroni adjusted probability value of 0.0067 is less than 0.05, this implies that the test is significant between the population growth and the water body.

Multiple Comparison Tests (Bonferroni Adjustment)

Table 9 shows the Bonferroni-adjusted probabilities. All six variables show significant pairwise relationships because their p-values are all < 0.05. This confirms that population growth is significantly related to changes in built-up area, farmland, vegetation, and water bodies.

Table 9: Multiple Comparisons

Covariance Analysis: Ordinary							
Date: 10/02/25 Time: 01:21							
Sample: 2006 2024							
Included observations: 19							
Bonferroni multiple comparison adjusted probabilities							
Covariance							
Correlation							
t-Statistic							
Probability	*Population Growth*	*Built_Up_ Area*	*Farmland*	*Light_ Vegetation*	*Thick_ Vegetation*	*Water_ Body*	
Population_Growth	2511842.						
	1.000000						

Built_Up_Area	19992.49	160.3836					
	0.996072	1.000000					
	46.38124	-----					
	0.0034	-----					
Farmland	3051.883	24.48575	3.738270				
	0.995947	0.999996	1.000000				
	45.65687	1389.568	-----				
	0.0098	0.0000	-----				
Light_Vegetation	-13638.91	-109.4265	-16.70628	74.66017			
	-0.995954	-0.999996	-1.000000	1.000000			
	-45.69336	-1424.338	-13152.53	-----			
	0.0053	0.0000	0.0000	-----			
Thick_Vegetation	-8161.476	-65.48031	-9.996960	44.67629	26.73408		
	-0.995955	-0.999996	-1.000000	1.000000	1.000000		
	-45.70423	-1409.087	-11900.24	20386.06	-----		
	0.0012	0.0000	0.0000	0.0000	-----		
Water_Body	-1199.572	-9.648707	-1.473128	6.583401	3.939461	0.582072	
	-0.992069	-0.998621	-0.998658	0.998660	0.998656	1.000000	
	-32.54215	-78.43763	-79.51181	79.55280	79.44343	-----	
	0.0067	0.0000	0.0000	0.0000	0.0000	-----	

In table 9 above, given that the variable skewness of all the variables is within the range of zero (0), it therefore mirrors a normal distribution among the variables. Also, the Jarque-Bera values of all the variables are greater than 0.05, which implies that the variables are normally distributed in the model.

Normality Tests

All variables exhibit near-zero skewness and Jarque–Bera probabilities above 0.05, indicating normal distribution of residuals and supporting model validity (Table 10).

Table 10: Separation of Means and Confirmation of Test of Significance

Parameters	*Population_ Growth*	*Built_Up_ Area*	*Farmland*	*Light_ Vegetation*	*Thick_ Vegetation*	*Water_ Body*
Mean	8610.789	39.33447	27.47716	62.59332	7.594000	0.967105
Median	8450.000	39.32500	27.48000	62.59000	7.594000	0.945000
Maximum	11427.00	60.16000	30.65400	76.79000	16.09000	2.250000
Minimum	6273.000	18.67000	24.30000	48.39700	-0.902000	-0.220000
Std. Dev.	1628.309	13.01129	1.986442	8.877385	5.312185	0.783843
Skewness	0.216021	0.003778	-0.000245	6.40E-05	-1.90E-16	0.092812
Kurtosis	1.803204	1.788969	1.793333	1.792922	1.793333	1.738702
Jarque-Bera	1.281694	1.161100	1.152703	1.153487	1.152702	1.286718
Probability	0.526846	0.559590	0.561945	0.561725	0.561945	0.525524
Sum	163605.0	747.3550	522.0660	1189.273	144.2860	18.37500
Sum Sq. Dev.	47724999	3047.288	71.02714	1418.543	507.9475	11.05937
Observations	19	19	19	19	19	19

A significant relationship exists among all six variables used/examined in this study. Significant and inverse relationship also among some of the variables: population and light vegetation, population and thick vegetation, population and water body; built-up area and light vegetation, built-up area and thick vegetation, built-up area and water body; farmland and light vegetation, farmland and thick vegetation, farmland and water body. Key environmental indicators, including vegetation cover, water bodies, and farmland, are declining rapidly in Eleme, driven by population pressure and limited environmental safeguards.

Global population growth of the last 200 years appears explosive on the historical timeline. The overall effects of this growth on living standards, resource use, and the environment will continue to change the world landscape long after. Hinrichsen and Bryant (2010) opine that rising population growth can lessen our quality of life because it destroys resources, such as water and forests, needed to sustain us, slows the dynamics of a healthy economy, and decreases the level of biodiversity upon which we depend. As the century begins, natural resources are under increasing pressure, threatening public health and development. Water shortages, soil exhaustion, loss of forests, air and water pollution, and degradation of coastlines afflict many areas, including Eleme. As the world's population grows, improving living standards without destroying the environment is a global challenge; thus, this study is crucial, considering the size of Eleme (138 km^2) and its natural resources, as well as its industrial base and attractiveness to job seekers.

Population growth in Eleme has been on the increase over the past 88 years, with its attendant pressure on the natural resources of the area. Dr. McKenzie Talbot, in his thesis of 1937 (cited in Obenade *et al*., 2020), gave the population of Eleme as 2,528, while the 1991 Population Census of Nigeria gave the population of Eleme as 80,715. By the 2006 Census figure as gazetted by the Federal Government in February 2009, the population of Eleme Local Government Area is 190,194. The population of Eleme grew rapidly from 2,528 in 1937 to 80,715 in 1991, representing an increase of 3,093 percent (meaning that it doubled 30 times) in 54 years. It is further observed that the population increased from 80,715 in 1991 to 190,194 in 2006, representing an increase of 137 percent in 15 years, meaning that its doubling time is about 12 years or less.

Particular concern about the situation in Eleme is the pressure on land use, food supply, waste generation and disposal, available energy and raw materials, and the problem of rapid urbanization occasioned by government acquisitions of land for the establishment and expansion of oil and gas operations and their accompanying influx of people into the area in search of employment opportunities. Shell Petroleum Development Company (SPDC), as cited in Ugochi *et al*. (2020), opines that one of the solutions identified to the problem of deforestation and environmental degradation in the Niger Delta Region is to assist stakeholder communities in developing livelihoods that reduce their dependence on the forest.

Many studies point to the alarming and deteriorating human conditions and nature's resources at unsustainable rates. FAO, in one of its studies, showed that in 64 of 105 developing countries studied, the population has been growing faster than food supplies and that population pressures have degraded some 2 billion hectares of arable land. It equally stated that while the supply of freshwater is finite, its demand is towering as

population grows and use per capita rises. It is projected that by 2025, when the world population is estimated to be 8 billion, 48 countries containing 3 billion people will face water shortages. The report further highlighted that nearly half of the world's original forest cover has been lost, and each year another 16 million hectares are cut, bulldozed, or burned. Forests provide over US$400 billion to the world economy annually and are vital to maintaining healthy ecosystems. Nonetheless, current demand for forest products may exceed the limit of sustainable consumption by 25%. As we know, the earth's biological diversity is crucial to the continued vitality of agriculture and medicine - and perhaps even to life on earth itself. However, human activities are pushing many thousands of plant and animal species into extinction, thus two of every three species are estimated to be in decline. More so, global warming resulting from increasing deforestation, greenhouse gas emissions, largely from burning fossil fuels, could cause droughts and disrupt agriculture. If the global temperature rises as projected, sea levels would rise by several meters, causing widespread flooding (Nath and Dhanaraju, 2025; Population Reports, 2000; Thiet, 2025).

Agumagu, Marchant and Stringer (2025) in their study which aimed to understand the changing distribution of various land cover types and their potential influence, considering that the Niger Delta Region is one of the rapidly growing regions in Nigeria, found that between 1986 and 2024, built-up and agriculture areas substantially increased by about 561% and 79%, respectively, with a concomitant decrease in mangrove and rainforest areas of about 54% and 42%, respectively. Rainforest and mangrove areas have decreased substantially over the study period, largely being replaced with built-up and agricultural land classes across the Niger Delta. Changes across the states were not consistent, with Delta, Bayelsa, Cross River, and Rivers States experiencing the highest decrease in rainforest, with losses of 64%, 55%, 45%, and 44%, respectively. The decrease in the mangrove, forest areas, and water bodies in the Niger Delta Region is anticipated to intensify runoff in the region, enhancing flood risk and impacts on livelihoods across the study region. As a result, mangrove restoration is becoming more extensively recognized as a significant approach for mitigating and adapting to the effects of climate hazards.

Interestingly, the results of this study provide clear evidence of increasing population growth and expansion of built-up areas in Eleme, with significant implications for natural resources and environmental quality. The analysis further shows that key environmental components like including farmland, light vegetation, thick vegetation, and water bodies, are all experiencing a downward trend. If these declines continue unchecked, they could threaten the area's ecological balance and carrying capacity over time. Overall, the findings align with the study's aims and objectives and are consistent with the results of similar research conducted elsewhere.

Conclusions

The evidence from this study demonstrates that rapid population growth in Eleme over the past two decades has fundamentally reshaped the ecological and economic landscape of the area. Population expansion, intensified by industrial activities, rural–urban migration, and inadequate spatial regulation, has driven a marked increase in built-up areas at the expense of farmland, vegetation, and water bodies. The strong negative correlations

between population levels and key environmental variables confirm that these land-use changes are neither incidental nor isolated; they reflect a broader pattern of unsustainable resource extraction and unplanned development. Ecologically, the decline in thick and light vegetation, shrinking wetlands, and the continuous loss of water bodies signal a deterioration of the natural systems that support biodiversity, regulate climate, and sustain agricultural productivity. Economically, these environmental pressures have contributed to falling crop yields, higher costs of resource procurement, reduced ecosystem services, and growing stress on already limited infrastructure. Together, these shifts indicate that Eleme is approaching a threshold where environmental degradation may begin to undermine long-term economic stability and public health. These findings underscore the urgent need for integrated strategies that link population management with sustainable resource governance. Effective responses will require coordinated action across land-use planning, environmental regulation, and social policy. Priority interventions should include the enforcement of zoning regulations, reforestation and wetland restoration programmes, pollution control measures, particularly in oil-bearing communities, and the expansion of community-based resource management initiatives. Equally important are investments in education, health, and job creation, which can reduce demographic pressure by improving human capital and promoting alternative livelihoods. Eleme's future environmental quality hinges on its ability to balance demographic growth with the sustainable use of natural resources. Without such balance, environmental decline will continue to erode economic opportunities and community resilience. With it, Eleme can transition toward a development pathway that protects ecosystems, sustains livelihoods, and ensures long-term well-being for its growing population.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*	*Author 6*	*Author 7*	*Author 8*	*Author 9*
Conceived and designed the research or analysis	Yes	No	No	No	No	No	No	No	No
Collected the data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	No	No	No	No	No	No	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supervision	Yes	No	No	No	No	No	No	No	No
Project Administration	Yes	No	No	No	No	No	No	No	No
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Overall Contribution Proportion (%)	20	10	10	10	10	10	10	10	10

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Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

Research on Indigenous Peoples and/or Traditional Knowledge
The author(s) solemnly declare(s) that this research has not involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

Research involving Plants
The author(s) solemnly declare(s) that this research has not involved the plants for experiment and field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of

the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

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